Two-stage gasification of biomass for the production of syngas with application to high-pressure chemical processes

R.Berends[*a] and G. Brem[a]
[a]TNO-MEP Dutch Research Institute for Environment, Energy and Process Innovation
Laan van Westenenk 501, PO Box 342, 7700 AH, Apeldoorn, The Netherlands
Fax: +31-55-549 3287; r.h.berends@mep.tno.nl

Synthesis gas or syngas is a gas mixture containing hydrogen and carbon monoxide. This mixture plays an important role as an intermediate gas in the production of several industrial products; for example Fischer-Tropsch liquids, methanol, ammonia and SNG. Nowadays the syngas is produced from fossil fuels, mainly coal and natural gas, but also from heavy oil residues and naphta. With the current developments towards sustainable production of fuels and chemicals, biomass can play an important role as feedstock for the production of synthesis gas. TNO-MEP, The Netherlands, is currently developing a two-stage gasification process for this purpose.

The two-stage gasification process
The two-stage gasification process consists of the following two steps (Figure 1).

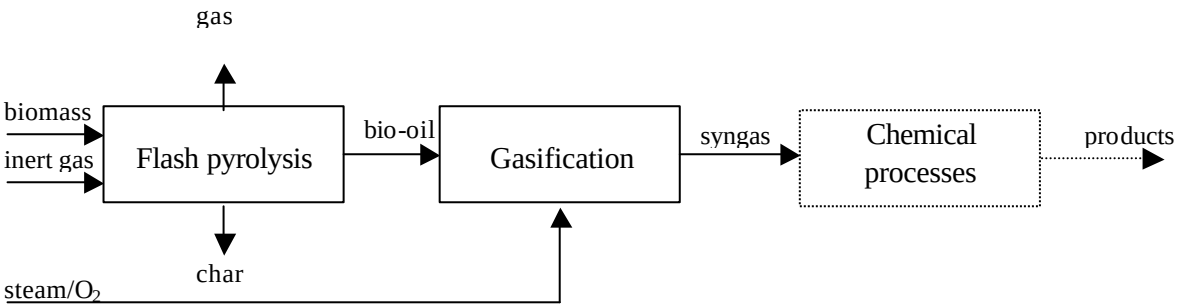

Figure 1. The two-stage gasification process

In the first stage biomass is pyrolysed to yield a maximum amount of bio-oil at atmospheric pressure and temperatures of approximately 500?C. The by-products in this stage are gas and char. The bio-oil is then pumped to the high-pressure gasification unit where it is thermally gasified with steam (and optionally oxygen) to yield syngas. This route has many advantages compared to conventional gasification routes for high-pressure down-stream processes like Fischer-Tropsch, methanol and ammonia synthesis:

- the two-stage gasification route gives rise to an easy operable high-pressure gasification step by use of a pump(for bio-oil) instead of a compressor (required for producer gas from direct gasification or produced syngas) with large economic advantages
- in the first - flash pyrolysis- step a large part of the contaminants (alkali's, chlorine, bromine, sulphur) are already removed and by feedstock pre-treatment or in-situ cleaning methods this removal can be increased, which results is a clean syngas, without the necessity of excessive gas cleaning
- by using a thermal gasification step instead of a catalytic one, problems concerning the deactivation of the catalyst are by-passed
- the use of high gasification temperatures results in a tar free syngas
- pyrolysis and the gasification/chemical synthesis can be geographically decoupled

Initial calculations have been carried out at TNO-MEP, based on commercial flash pyrolysis units and assuming thermodynamic equilibrium of the syngas product at the gasifier outlet. Basis for the calculations was that the heat and electricity demand is internally fulfilled, which includes the drying of wood to 15wt% water, required for the pyrolysis step. This is achieved by combustion of the produced char, gas from pyrolysis and part of the syngas product. According to this procedure high syngas yields (0.73 kg syngas/kg dry wood, with syngas for heat supply already deducted) can be achieved. The generated syngas has an H_2/CO-ratio of 1.1, which can be adjusted by a subsequent water-gas-shift unit.

Conclusion

Two-stage gasification of biomass is an interesting route for the production of syngas for high-pressure down-stream processes. Initial calculations show that high syngas yields can be achieved including total internal energy integration. The produced syngas is free of tar, inert gas (nitrogen) and contaminants. By down-stream processing of the produced syngas the process can be adapted for different chemical conversion routes.